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Priority Papers #2
E. Burns
01/03/02

3662.

APPLICANT: ROWE ET AL)

Application No.: 09/988,991)

Filing Date: 11/21/01)

For: BROADCAST DATA RECEIVERS AND ADAPTIVE NATURE OF AMPLITUDE GAIN CONTROL THRESHOLDS TO OPTIMISE RECEIVED SIGNAL QUALITY)

Art Unit: 3662)

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Enclosed herewith is a certified copy of British Patent Application No. 0028300.2 for which the above-identified patent application claims priority from.

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Respectfully Submitted

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1. Your reference — **GW-G30594**

2. Patent application number *(The Patent Office will fill in this part)* — **0028300.2** — **21 NOV 2000**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — **Pace Micro Technology Plc**
Victoria Road
Saltaire
Shipley
BD18 3LF

Patents ADP number *(if you know it)* — 7588569001

If the applicant is a corporate body, give the country/state of its incorporation — **U.K**

4. Title of the invention — **Adaptive Nature of AGC Thresholds and Gains to Maximise Received Signal Quality**

5. Name of your agent *(if you have one)* — **Bailey Walsh & Co.**

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — **5, York Place**
Leeds
LS1 2SD

Patents ADP number *(if you know it)* — **224001**

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / years)*

7. If this application is divided or otherwise derived from an earlier UK application, the earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer "Yes" if:* — **Yes**

a) any applicant named in part 3 is not an inventor, or

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Description	8
Claim(s)	
Abstract	
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
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11. I/We request the grant of a patent on the basis of this application

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Adaptive Nature of AGC thresholds and Gains to Maximise Received Signal Quality

The invention to which this application relates is to the use of items, particularly, but not necessarily exclusively, of the type used in broadcast data receivers.

Direct conversion (or ZIF – zero intermediate frequency) satellite (and other) tuners often employ a multiplicity of AGC loops to cater for varying signal input level. Unlike a conventional (superheterodyne) tuner the ultimate channel filtering is performed very near the actual demodulation stage of the processing of the signal and removed from the antenna input as far as possible.

Further, there is usually no input tracking filter as part of the tuner. The result is that the RF amplifier, mixer IF (intermediate frequency) stages and A/D (analogue to digital converter) are subject to adjacent channel signals – often the whole transponder's content and this can severely affect the quality of the signal which is used for subsequent processing and, in due time, affect the quality of generation of the television programme for the user.

Optimum receiver performance is dependent upon optimum gain distribution within the receiver, which is not dependent just upon the required signal quality, but also upon the rest of the signals visible to the various stages within the receiver.

Current AGC systems often adjust AGC control in a manner which is purely determined by the level of the wanted signal only. Some slightly more advanced systems have a wider band AGC detector that controls the wider band stages of the receiver, but both systems will not necessarily provide optimum

results for a given receive installation or satellite transponder. In both cases the AGC loop characteristics are set at the stage of product design to be a compromise between the conflicting requirements of 'single signal' environments and 'multiple signal' environments.

It should be noted that reference to receivers which receive signals via satellite transmission means is only given here as an illustration, and the invention as set out is equally applicable to any signal whose quality can be measured in a multi-signal environment (e.g. cable; terrestrial digital date television transmission systems.)

Many systems require the optimisation of a certain measured value (henceforth called the 'metric') by varying a single control parameter. The following shows a way of achieving this that is robust to change of the optimum point, and noise, on the metric., both Gaussian and Impulsive.

No prior knowledge of the shape of the metric versus control variable curve is required, other than it has a single optimum point.

The inventive step in this aspect is to dynamically control the AGC characteristics of the multiplicity of AGC loops to maximise received signal quality. In effect the receiver adapts to a particular receive installation and satellite transponder.

In a digital receiver the signal quality is easily measured in the demodulator error correcting circuitry and requires no human intervention. The algorithm in one embodiment would be 'pick the best from N options' or in an alternative embodiment a complex multidimensional parameter maximisation search is adapted (or any step in between).

Another new optimisation method uses a combination of the principles of 'fuzzy logic' and non-linear filters.

This invention presents in a further aspect a robust method for converging the optimum value of a measured metric, say bit error rate (BER), by altering a control value, say an AGC threshold.

It can cope with a very noisy metric, even one suffering from impulsive noise, and ITS optimum point changing over time.

This robustness is achieved by a novel combination of modern signal processing methods, namely non-linear filtering and fuzzy logic. It is computationally less expensive to implement than a traditional control approach to the same problem, and is useful for optimisation problems outside of the set top box environment it was originally intended for.

Specific embodiments of the invention are now described with reference to the accompanying figures.

Referring to Figures 1 and 2, when initially tuned to a signal the tuner will use default AGC settings. These are what would normally be used if adaptive AGC were not employed – as is the case at present. However, once the signal is acquired, the adaptive algorithm comes into play. For instance, if there are larger adjacent carriers, it is better to have more gain in the base band after some initial filtering. However, if the wanted signal is larger or closer to the noise floor then more RF gain is better. So the exact optimum gain distribution is largely dependent upon many external factors.

The basis of the invention is that there is an algorithm that maximises the wanted signal's quality based upon manipulation of gain distribution. In the simplest case there are two (or more) predefined gain balances and the best is chosen based upon the received signal bit error rate (BER).

A more complex case involves a two dimensional search in 'AGC space' to minimise the BER. In this case if there are more than two AGC loops then the dimensions to be searched also increase.

A typical ZIF tuner is illustrated in Figure 1. this is representative of current generation of ZIF tuners. In use adjustment of the AGC threshold control voltages changes the balance of the gain distribution between the RF and Baseband gain controlled stages to optimise performance for the particular signal situations found.

A more advanced ZIF tuner is illustrated in Figure 2. Here there is a separate wideband AGC loop for the RF gain controlled amplifier. This is better than the previous tuner because the gain of the RF stage is controlled by the total number of signals present in the RF stage, and not just by the wanted signal. However, the baseband filter is still not matched to the signal and energy from adjacent channels may well appear at the input of the analogue to digital converter, reducing the number of bits available for the wanted signal. If this baseband gain is controlled by the power in the wanted signal then the system performance is sub-optimal in the presence of strong adjacent channel signals, i.e. the gain of the baseband amplifier should be such as not to overload the A to D converter and any additional gain made up for in the digital gain controlled stage.

However, if there are no significant adjacent channel signals then it is better to maximise the baseband gain to make best use of the available bits. If a multidimensional 'AGC space' search algorithm is employed then the area of search may have to be restricted to certain bounds to avoid false peaks in the signal quality.

It is proposed that the algorithm is applied at least for every tune operation, as this will not slow down the signal acquisition. Preferably the system may be periodically re-searched for best performance. Also, it is advantageous to learn and store the optimal settings for a given frequency and band, and so minimise the resulting search effort required on reacquisition.

ZIF type tuners (for example) suffer from a disadvantage when it comes to multiple signal handling because the channel filtering is near the end of the signal processing chain, so previous stages are exposed to unwanted, uncooperative signals. Dynamic optimisation of the wanted signal quality improves the operational margin of the receiving system, so any further system degradation can be better tolerated.

A further aspect of the invention is now described wherein a satellite installation with a sub optimum installation (perhaps in a fringe area with a wide variation of carrier signal levels within the 'visible' transponder) would be more tolerant of further signal degradations (e.g rainfall) upon satisfactory operation of the receiver system.

The preferred method of optimisation will be explained using an example where the optimum point is the minima of the metric, see Figure 3, but it is trivial to re-write the fuzzy rules to operate in a situation where the optimum point is the maximum of the metric.

Consider a portion of the curve shown in Figure 4. The current value of the control variable gives the point 'O'. The gradient around this point will show which way to change the control variable to get closer to the optimum. As the gradient becomes less, the amount by which the control variable should be changed should also become less so that the optimum point is not stepped over.

A simple way of getting the curve gradients is to alter the control variable value, and after the change has had an effect, re-measure the metric. This is done for a point below in value 'B' and above in value 'A', with respect to the starting value. There is now enough information to calculate the gradients, which can be performed in a conventional manner. Both gradients can be evaluated in the same sense, i.e. with respect to the positive direction of the control variable. If the offset between 'O' and 'B', and that between 'O' and 'A' are the same, then a value proportional to the gradient can be obtained by dividing the metric value at 'B' by that at 'O', and that at 'O' by 'A'. The overhead here would be choosing the order in which to do the divisions (always larger divided by smaller), and the application of a sign as required by the fuzzy logic rules.

These gradient samples will be noisy. The filtering inherent in fuzzy logic will take care of Gaussian noise, but if the metric suffers from impulsive noise, the gradient samples could be badly misclassified in the fuzzification operation. Just taking an average of several gradient samples, or using a digital filter, could still result in a very unrepresentative value as an impulsive noise event could give a metric measurement that is so far from optimum, it takes a while to 'de-accumulate' from the filter.

In accordance with the invention, this spiky noise is removed by using a median filter, a form of non-linear filter wherein a series of samples are ranked in numerical order, and the middle value is chosen as representative.

To illustrate, if there are 5 samples, sample 3 of the ranked samples would be the representative one.

The filtered gradient samples can now be passed to the final stage.

A standard fuzzy logic block, as shown in Figure 5, should process the gradient samples.

The input membership functions should take the form of Figure 6. It is not recommended to reduce the number of classes, but more could be added for increased accuracy, at the expense of more computational effort if required.

The all important fuzzy rules are given in table 1. It should keep its form even when the numbers of input and/or output classes are increased. For the example given, the top-left 4 entries should never occur (as these refer to a maximum in the curve) and that is why they have 'do nothing' rules associated with them.

Gradient 'BO' is gradient estimate from point 'B' to 'O', similarly for Gradient 'OA'. Columns and row headings are from the input membership functions. Table entries refer to the output membership functions.

The output membership function should have the form of Figure 7. In one embodiment, symmetric membership functions can be used, as this is computationally less demanding.

To recap, the system overall block diagram is given in Figure 6, 8.

This approach means that no prior knowledge of the shape of the measured metric vs. control value is required, indeed, it is designed to work in situations where this curve changes with time (as other uncontrolled, and possibly uncontrollable, variables change). It can cope with this metric being noisy, and even suffering from impulsive noise, and is less computationally expensive than traditional control methods due to the implicit filtering in fuzzy logic and a median filter being simple to implement. The digital filters required in a traditional scheme would be computationally expensive.

The idea for this submission, although described with reference to the method to optimise the AGC take-over point against the measured metric of BER for a demodulator and which gives the best BER depending on whether it was limited by the tuner noise-figure, adjacent channel interference or intermodulation products (Ips), can be extended to several other control loops within a product, e.g setting the correct black level. All of these have metric vs. control value curves that are non-constant, and have noisy metrics.

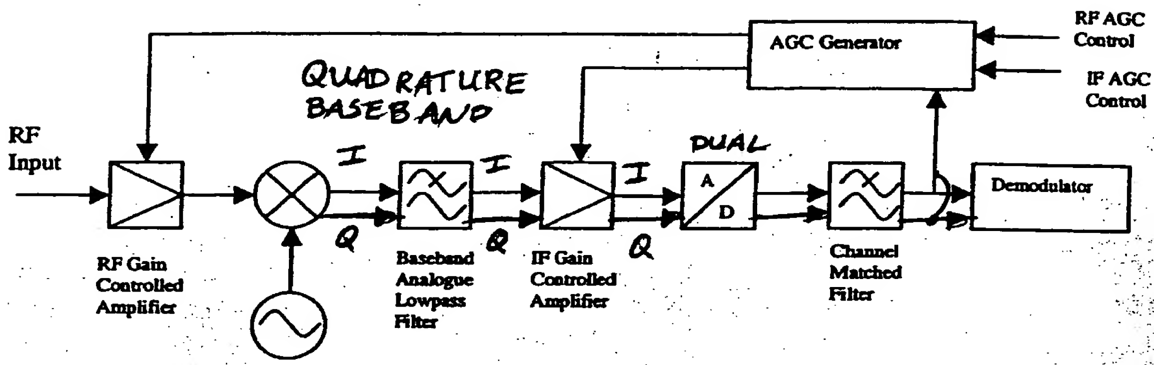


Figure 1

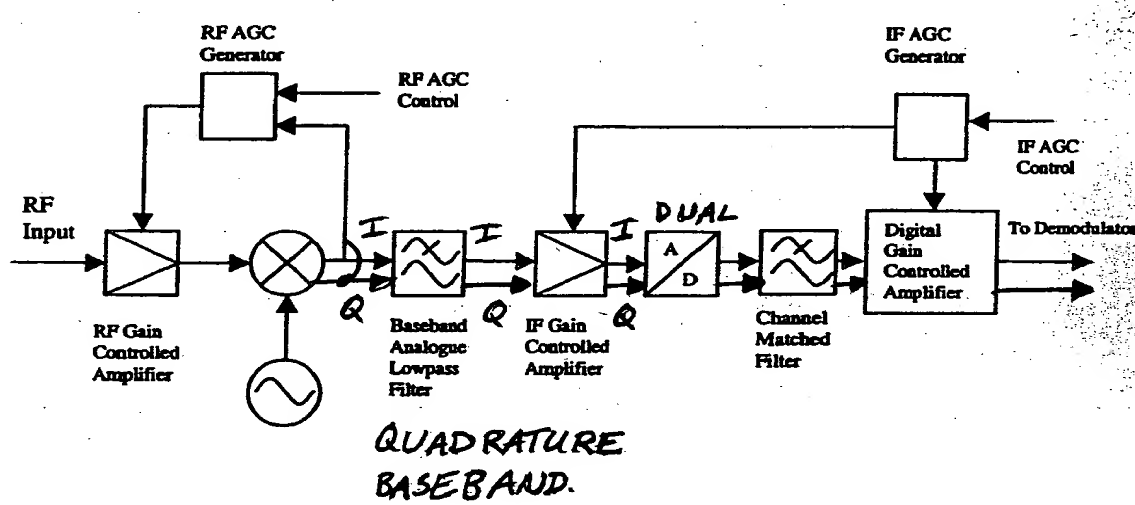


Figure 2

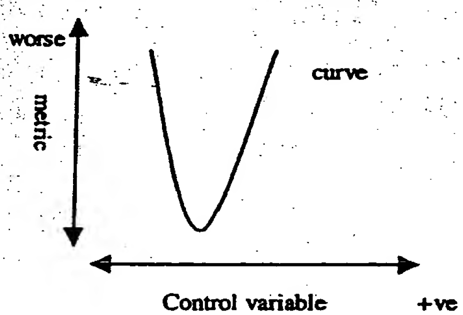
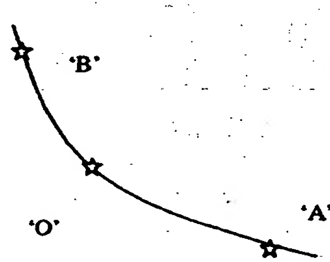


Figure 3

Figure 4



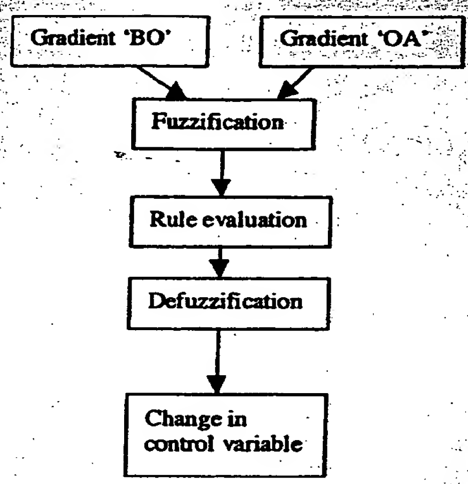
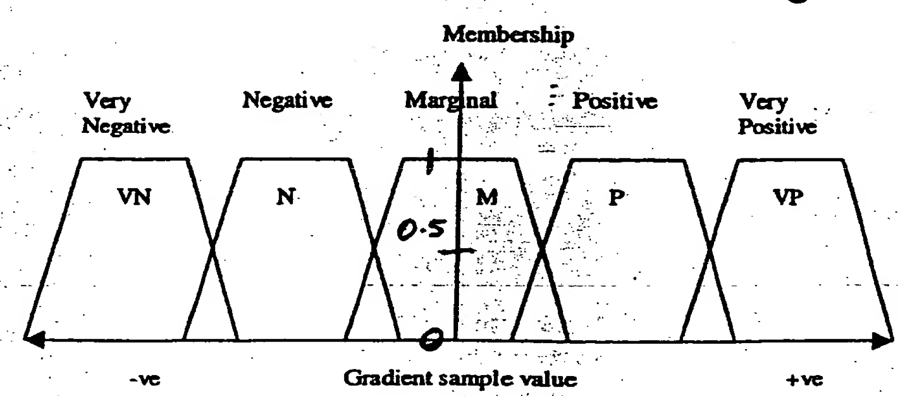


Figure 5

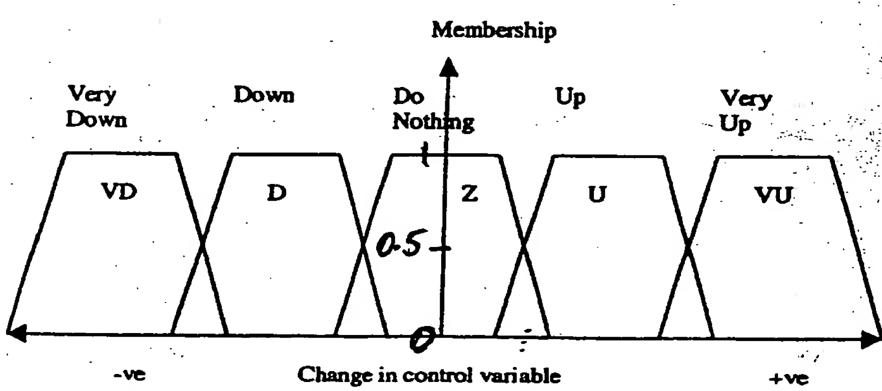
Figure 6



Gradient 'OA'	Gradient 'BO'				
	VN	N	M	P	VP
VP	Z	Z	Z	D	VD
P	Z	Z	Z	D	D
M	Z	Z	Z	Z	Z
N	U	U	Z	Z	Z
VN	VU	U	Z	Z	Z

Table 1.

Figure 7



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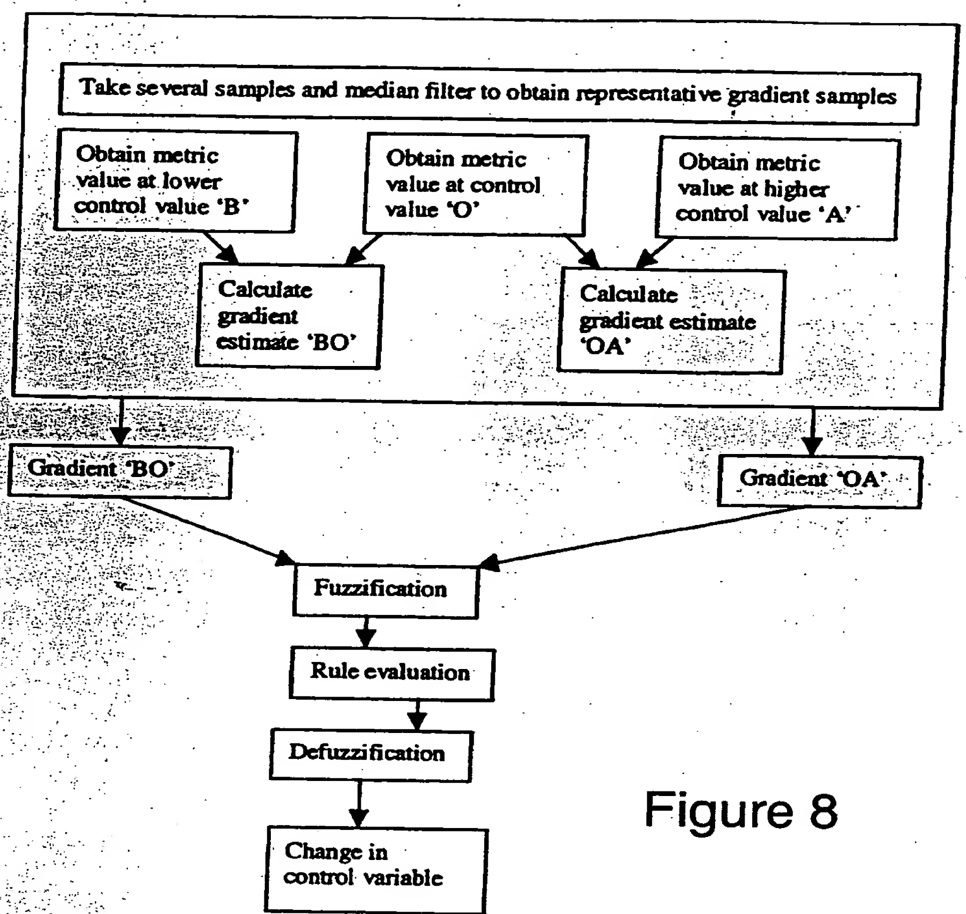

Take several samples and median filter to obtain representative gradient samples
Obtain metric value at lower control value 'B'
Obtain metric value at control value 'O'
Obtain metric value at higher control value 'A'
Calculate gradient estimate 'BO'
Calculate gradient estimate 'OA'
Gradient 'BO'
Gradient 'OA'
Fuzzification
Rule evaluation
Defuzzification
Change in control variable

Figure 8